A New Mapping Method for the Moon With the Chang'E-1 Data

Lingli Mu, Chunlai Li , Jianjun Liu, Xin Ren, Xiaoduan Zou

National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012, China. mull@nao.cas.cn

Abstract. On October 24, 2007, the first lunar probe—Chang'E-1 was successfully launched into the space. A new era for China to explore the mysteries of the universe is coming. Chinese scientists and cartographic experts have produced lunar map series using the Chang'E-1. This map series is based on a new mapping method, which is satisfied with paper mapping, globe making and electric map releasing. How to map the new planet (including the Moon) with high efficiency is main problem for the planetary cartographic experts. In this paper, a new mapping method for the Moon will be introduced based on the spatial database.

Keywords: Chang'E-1, Lunar Mapping, DEM, DOM

1. Introduction

Since the end of the 1950s, a series of lunar exploration activities have been carried out, and huge lunar topographic and morphologic data were acquired. To enhance human being's knowledge of the Moon, an amount of lunar maps was released. In the early period (1960-70s), the main lunar maps were published by the Soviet Union and USA, such as *Lunar Astronautical Chart (LAC) Series, Atlas Obratnoi Storony Luny, Apollo Intermediate Chart Series, The Lunar Topographic Orthophotmaps and Lunar Orthophotomaps Series* and so on.

From the beginning of the 21st century, lunar exploration entered into another thriving age. Many lunar missions including SMART-1, Kaguya, Chang'E-1/2, Chandrayaan, LRO, ARTEMIS and GRAIL were launched. In 2004, Ben Bussey and Paul Spudis compiled *The Clementine Atlas of the Moon*. In 2010, Science Achievements Series of China's Lunar Exploration Program came into beings, which is composed of papers, maps, atlas and globes.

In this paper, the Chang'E-1 Data, method and map series will be introduced.

2. Data for the Chang'E-1 Mapping

Until July 1, 2008, the Chang' E-1 probe had get the images covering the whole Moon completely by Three-Linear-Array CCD stereo camera and 9 million distance data by altimeter. After Data preprocessing, photogrammitric surveying, registering and mosaicking, the Chinese scientist got the global Digital Orthophoto Map (DOM) and DEM (Digital Elevation Model) data of the Moon for the first time. The space resolution of the global DOM is 120 m with plane root mean square error (RMS) of 192m. The space resolution of the global DEM data is 500m with elevation RMS of 120m. In addition, another lunar global DEM was derived from the altimeter data with resolution of 3 km.

For understanding the map, National Astronomical Observatories (NAOC) collected the lunar feature names released by IAU WGPSN and translated them into Chinese. Above data were stored in spatial database.

3. The New Mapping Method

The Chang'E-1 DOM and DEM data is very useful to show the globe topographic and morphologic characters of the Moon. But it is not an easy job to use huge data for mapping so wide area. To satisfy the reader's sight psychology and make it more efficient to understand the lonely planet, it is necessary to create a new method to present the data. For the Chinese public or children, the most important thing is to illustrate the whole shape of the Moon and terrain of the lunar surface, specially the far side of the Moon. However, for the scholars and college students, they want to get more detailed map information. In the digital time, paper map or atlas is not portable, but the electric or digital maps become necessary and popular. To meet above demands, the new mapping method brings out a mapping frame based on spatial database.

3.1. Mapping Frame

The new mapping method provides a uniform mapping frame, which is a perfect way to design and produce different map products for the Chang'E map series. The mapping frame covers the map series planning, standardizing, map designing, data processing and map editing. All of the map data including the DEM data, DOM data, contour data, annotation data, map template data and so on, are stored in the database. The map maker can use

the ArcMap or Arc Catolog to access those data. After edited, the new map data should be re-stored in the database. This method can share the map templates and data that makes it convenient to edit map series. The mapping frame is described in the Figure 1.

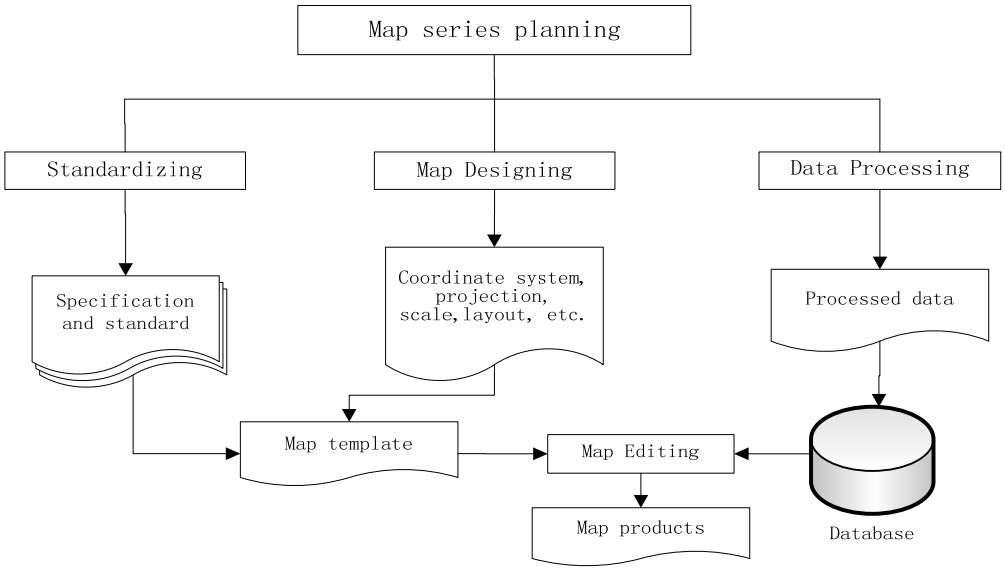

Figure 1. Content of the mapping frame for Chang'E map series.

3.2. Map series planning

For the map series planning, the main job is to define map series content, map presentation and specifications.

The map series of the Chang'E-1 aim to show the global topographic and morphologic characters of the Moon with relatively high resolution data. In the map series, all of the maps are classified by fixed type and unfixed type. The fixed maps are hard copies, such as atlases, small scale maps and globes. The atlas's focus is on the special information at large scale. The small scale map and globe should portrait the whole topographic characters of the lunar surface. But the unfixed maps are active digital products, which can be zoomed in, zoomed out, panned and rotated by mouse.

To keep the uniform style, the hard copy and digital products should share the same standards, presentation styles and data source.

3.3. Standardizing

The main content of standardizing covers lunar coordinate system, subdivision, annotation translation and data storage. As the national standard, *the lunar coordinate system*, written by NOAC, give the mathematic founda-

tion for map data. The lunar coordinate system defines the reference ellipsoid and other geometric parameters of the Moon.

For the large scale atlas, NAOC have finished the industrial standard: *Subdivision and numbering for the lunar primary scale topographic maps*. This standard will be released in this year. The range (in Table1) of the primary scale covers 1: 2 500 000, 1:1 000 000, 1: 500 000, 1: 250 000, 1: 100 000, 1:50 000, 1: 25 000 and 1: 10 000.

Latitude range	Longitude range	Projection
84°N～90°N	360°	Polar azimuthal projection
70°N～84°N	45°	Lambert conformal conic projection
56°N～70°N	30°	
42°N～56°N	24°	
28°N～42°N	20°	
14°N～28°N	18°	
0°N～14°N	18°	Mercator projection

Table 1. projection used for the subdivision maps.

IAU WGPSN has release about 9099 lunar feature names. To help Chinese to understand the lunar features, NAOC has setup an specification *(Lunar Feature Name in Chinese and Code*) to translate the names. As for the data format, the raster and vector data are stored in database with GeoTiff, PDS or SHP. As the result of the mapping frame, the map product is stored in AI and EPS data formats.

3.4. Map designing

In this map series, the size and projection of products are different. The dimension of the hard copy is fixed (34cm * 37cm). As for small scale map, the size is not more than 150cm * 300cm. To illustrate the terrain of the Moon, radius of 10cm, 16cm and 53cm are designed for the lunar globes. For the digital map products, the map scale is decided by the original resolution of the data.

To control the distortion of the subdivision maps in the atlas, Mercator projection, Lambert projection and Polar Azimuthal projection are adopted in equator-low latitude zone between 14°S-14°N, middle latitude zone of 84°-14° and polar region zone of 84°-90° respectively(in Table 1). Mollweide projection is used for the global small scale map. For the digital map, Mercator projection is selected.

Another key design is the color style of the shade relieves, which appear in the topographic map and globe. According to the elevation, the graduation tints is designed to illustrate the terrain altitude. The areas of low altitude

below the geoid are shown in blue tones, and those above the geoid in deep yellow tones.

Based on the standards and designs, the map designer will make a map layout and a map template (or prototype) for each map products. After optimizing, the map editor uses the template to update map data for other mapping area. This method can save much time and keep the map series in the uniform style.

3.5. Data processing

For the atlas, the global image data and DEM data are divided into 188 map subdivisions of 1: 2 000 000. Each subdivision map data is transformed with different projection according to table 1. The DEM data can't show the topographic characters directly. In the topographic map, the DEM subdivision data are used to make the shade relieves as background maps. The contours with 500m intervals are extracted from DEM data to present the elevation information. After cartographic generalization, the contours data are registered at the same scale as the shaded relieves.

To show the morphologic characters, the main job of image processing is to enhence and unify the tone of the lunar image map, and transform the projection. All of the annotations marked on the map were selected from IAU WGPSN and translated into Chinese.

Above data called as processed data are stored in the database.

3.6. Map editing

Based on the spatial database, the editors use the ArcCatolog to manage and access the original data, processed data, edited data, template data and publishing data. Under the mapping frame, the editor uses the processed data to update the map data of the template, which is a convenient and efficient method to create new subdivision maps as publishing data. After quality check, the publishing data will be sent to the printing house.

4. Conclusion

Under the mapping frame, NAOC, Sinomap Press, Surveying and Mapping Publishing Press have being released 7 kinds of map in recent 3 years. The new mapping method for the Moon with the Chang'E-1 data keeps the same styles of the map series in different modes. The detailed introduction to the map series is following.

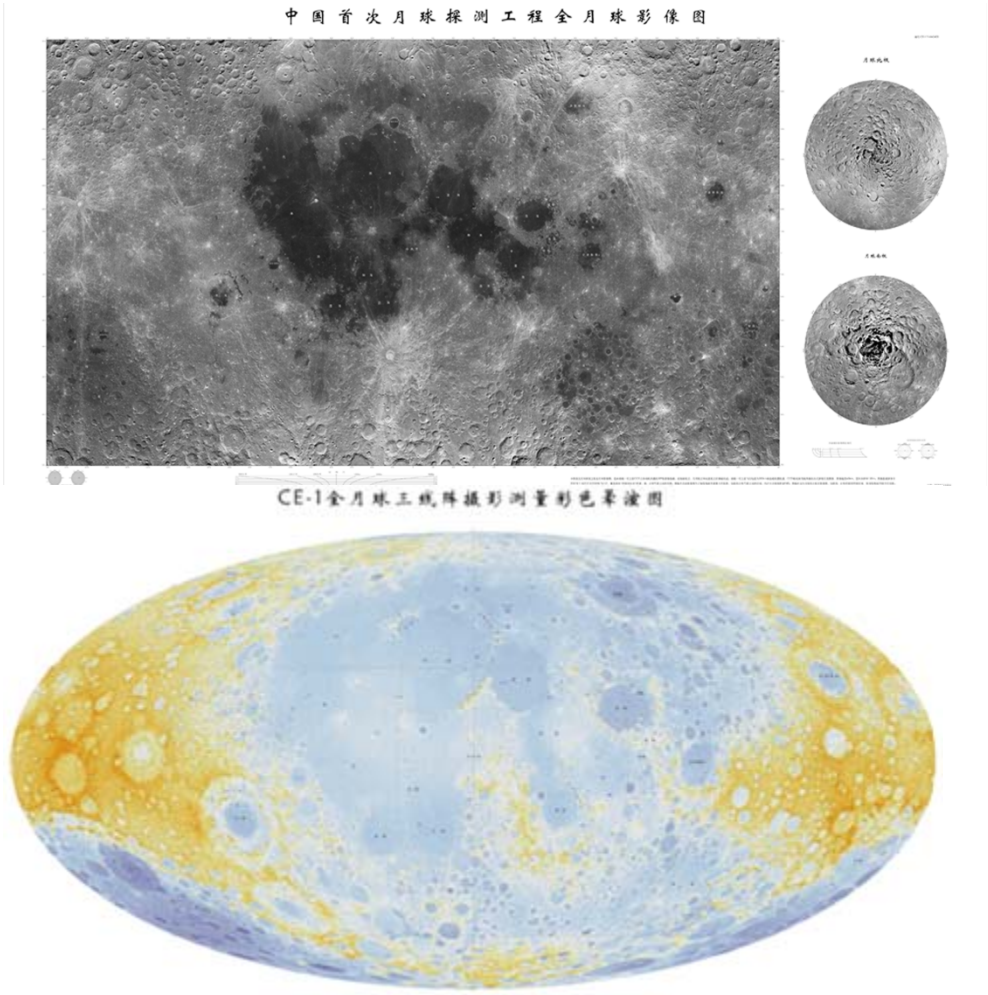

Figure 2. The small scale map of the Moon: The Global Orthophoto Map and Shade Relief of the Moon from China's First Lunar Probe Chang'E-1.

Figure 3. Atlas: The Chang'E-1 Image Atlas of the Moon and The Chang'E-1 Topographic Atlas of the Moon.

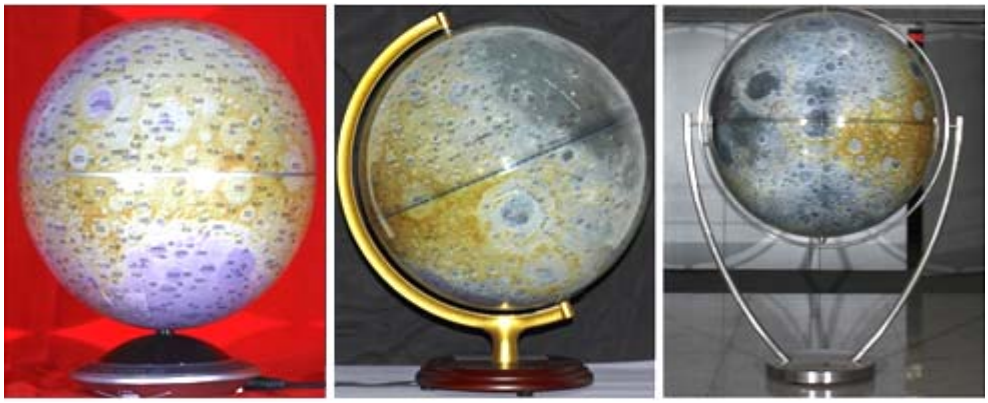

Figure 4. The Moon Globes of Chang'E-1 with radius of 10cm, 16cm and 53cm.

Figure 5. Digital lunar map of the Chang'E-1 on web (http:// moon.bao.ac.cn).

Above products are all marked by bilingual annotations that is the first time to produce map about extraterrestrial body in China. The result shows that this new method provides an efficient mapping frame and will build up a new mapping study direction in China. In the future, the lunar map series will being play an important role in the lunar study and science popularization

References

Li C L, Liu J J, Mu L L, et al(2010). The global image of the Moon obtained by the Chang'E-1: Data processing and lunar cartography. Sci China Earth Sci, 53(8): 1091-1102

Li C L, Ren X, Liu J J, et al(2010). Laser altimetry data of Chang'E-1 and the global lunar DEM model. Sci China Earth Sci, 53(11): 1582-1593

Ouyang Z Y, Li C L, Zou Y L, et a(2010). Chang'E-1 Lunar mission: An overview and primary science results. Chin J Space Sci, 30(5): 392-403

Ouyang Z Y, Li C L, Zou Y L, et al (2010). Primary scientific results of Chang'E-1 lunar mission. Sci China Earth Sci, 53(11): 1565-1581.